are separated by a partition of kaolin or other similar insulating material.

I have thought it well to describe, as nearly as possible in the words of the inventor, the electric candle, which is now the subject of so much attention in its application to electric lighting; so that its relation to what follows may be more clearly perceived. A remarkable peculiarity of the direct current in electric lighting is that of its consuming the positive carbon at twice the rate of the negative one, and while the negative carbon is a pointed cone, like that of a pencil, the positive pole takes the form of a hollow cavity or crater.

M. Jablochkoff's early experiments seem to have been made with the direct current, and hence his carbons are described as being of unequal thickness, in order that the positive and negative carbons of the candle might be evenly consumed. When the alternating current is used for producing electric light both carbons are of the same thickness, and are consumed at an equal rate, and both points terminate in regular cones. This property of the alternating current, besides other advantages, always maintains the luminous point in the focus of any optical apparatus used in connection with it, that is, when the carbons are placed end to end, as I had occasion to point out in a former paper read before the Society in 1873, on an electro-magnetic induction machine for producing alternating currents.

M. Jablochkoff, in the course of his experiments, would appear to have met with some difficulties in adapting the direct or continuous current to a system of lighting with his electric candles, and now uses the alternating current for this purpose. The candle has also been simplified by substituting a slip of plaster of Paris for the cartridge and partition of kaolin formerly employed.

To produce the alternating currents, however, to supply a number of lights, it was found necessary to employ powerful electro-magnetic induction machines, excited by the currents from other smaller machines, according to the principles laid down in my paper read before the Royal Society, and published in the *Philosophical Transactions* of 1867. From sixteen to twenty lights are produced from one of these electro-magnetic machines, each light absorbing about one-horse power.

The system of electric lighting above described would now seem to be definitely established in some places as a substitute for gas, and visitors to the French capital during the present summer will have been struck with the fine effects produced in the avenues and squares where the light is displayed.

My connection with the history of this system of lighting placed me in a position to make some experiments with the Jablochkoff candle, and led to the discovery of the following facts. One of the conditions necessary for producing a constant light from the candle, in its most recent form, was that the quantity and intensity of the alternating current should be such that the carbons consume at a rate of from four to five inches per hour. If the electric current were too powerful, the carbons became unduly heated, and presented additional resistance to the passage of the current; the points at the same time lost their regular conical form. If, on the other hand, the current were too weak, the electric arc played about the points of the carbons in an irregular manner, and the light was easily extinguished by currents of air.

In the course of these experiments I was struck with the apparently insignificant part which the insulating material played in the maintenance of the light between the carbon points; and it occurred to me to try the effect of covering each of the carbons with a thin coating of hydrate of lime, and mounting them parallel to each other in separate holders, and without any insulating material between them. The use of the lime covering was intended to prevent the light from travelling down the contiguous sides of the carbons. On completing the electric circuit the light was maintained between the two points, and the carbons were consumed in the same regular manner as when the insulating material had been placed between them.

Two plain cylindrical rods of carbon three-sixteenths of an inch in diameter and eight inches long, were now fixed in the holders parallel to each other, and one-eighth of an inch apart. The strength of the alternating current was such that it would fuse an iron wire 0·025 of an inch in diameter and eight feet in length. On establishing the electric current through the points of the carbons by means of a conducting paste composed of carbon and gum, the light was produced, and the carbons burnt steadily downwards as before.

Four pairs of naked carbons mounted in this manner were next placed in series in the circuit of a four-light machine, and the light was produced from these carbons simultaneously, as when the insulating material was used between them. The light from the naked carbons was also more regular than that from the insulated ones, as the plaster of Paris insulation did not always consume at the same rate as the carbons, and thereby obstructed the passage of the current. This was evident from the rosy tinge of the light produced by the volatilisation of the calcium simultaneously with the diminution of the brilliancy of the light from the carbons.

The only function, therefore, which the insulating material performs in the electric candle, as shown by these experiments, is that it conceals the singular and beautiful property of the alternating current to which I have directed attention.

As I have already said, the strength of the alternating current must bear a proper proportion to the diameter of the carbons used, and when a number of such lights are required to be produced in the same circuit, the quantity and property of the current will remain constant, while the tension will require to be increased with the number of lights.

This simple method of burning the carbons will, I believe, greatly further the development of the electric light, as the carbons can be used of much smaller diameter than has hitherto been possible. They may also be of any desired length, for as they are consumed they may be pushed up through the holders without interrupting the light. One of these developments will be a better method of lighting coal and other mines. In this application the alternating currents or waves from a powerful electro-magnetic induction machine may be used for generating, simultaneously, alternating secondary currents or waves in a number of small induction coils, placed in various parts of the mine. The light may be produced in the secondary circuits from pairs of small carbons inclosed in a glass vessel having a small aperture to permit the expansion of the heated air within. Diaphragms of wire gauze may be placed over the aperture to prevent the access of explosive gas. By generating secondary currents or waves without interrupting the continuity of the primary circuit, the contact-breaker is dispensed with, and the subdivision of the light may be carried to a very great extent.

A STUDY IN MAGNETISM

THE name of Faraday will go down to posterity foremost amongst the names of the scientific men of this century, for the simple comprehensiveness and original beauty of his researches in electricity and magnetism; chiefly, perhaps, for his discovery of magneto-electricity—the kind of electricity that can be induced in conductors which are caused to pass near magnets. Those who have carefully read Faraday's works know how he was led to this discovery by the conception he had formed of magnetic force. Until his time magnetic

attractions and repulsions had been explained as a kind of action-at-a-distance. Faraday explained them as the results of the action of the medium filling the intervening space; and he gave several indisputable proofs that the space surrounding a magnet was thrown into a peculiar condition by the presence of the magnetism. Two centuries previously another Englishman, as uniquely

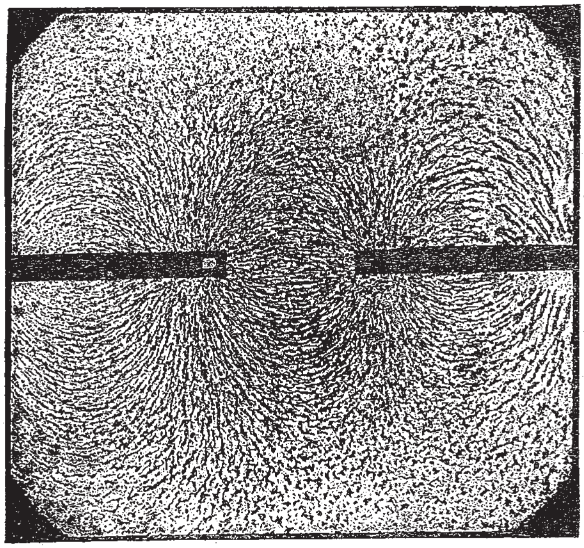

Fig. 1.

great if not greater, Dr. Gilbert, had in his famous treatise "De Magnete," told how iron filings sprinkled on a piece of card beneath which a magnet lay, assumed certain mysterious lines. To these lines Faraday gave the name of *lines of force*, and showed that they represented, wherever they went, the direction and strength of

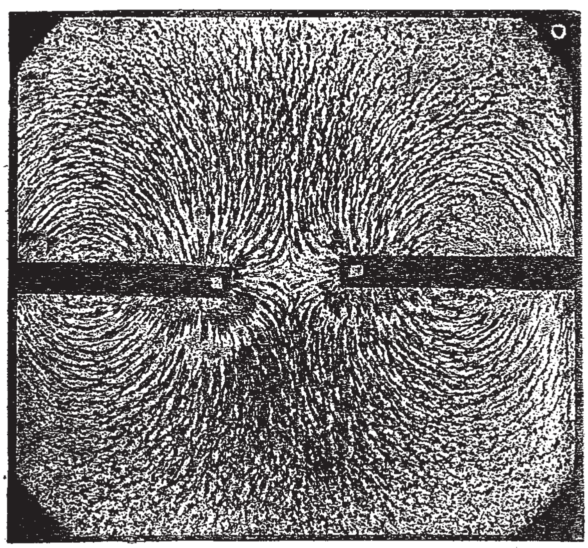

Fig. 2.

the magnetic force. His imagination seized upon these mysterious lines, and he saw all space, wherever a magnet had influence, traversed by them. He perceived that they were in some way bound up with that which was mysterious and unexplained in this seeing action-at-a-distance. He found them to react on one another, and to follow certain definite laws ascertainable by experiment. In the volumes of his researches he filled several entire plates with drawings of the figures assumed by the lines under various combinations. They had taught him to anticipate magneto-electricity and electro-magnetic rotation. He had diligently followed them up from the hint afforded by Dr. Gilbert's experiment with the iron filings. He had begun to apply the method to

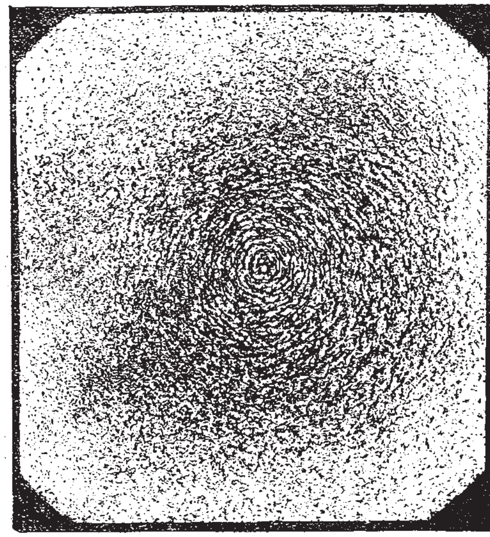

Fig. 3.

the investigation of the interaction of electric currents, when the decay of age overtook him, and the research dropped from his grasp. Had he lived the study which the writer of the present article is about to narrate would have been completed long ago.

The experiment of laying a card or a sheet of paper

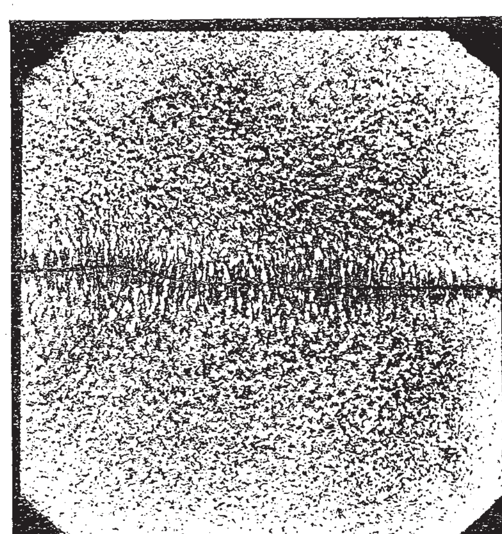

Fig. 4.

upon a magnet, sprinkling over it fine iron filings, and then tapping the card gently so as to allow the filings to take up their places in the "curving lines of force," is one which always possesses a peculiar interest and fascination for youthful electricians. Two other experiments, due originally to Musschenbroek, are not quite so familiar, though they are as simple; and since they have

a special bearing on that which follows, we will mention them in detail.

Let two bar-magnets of steel be placed on the table with the north-seeking pole of one towards the south-seeking pole of the other, but not touching. Over these lay a sheet of stiff writing-paper, or card, or a sheet of window-glass. Fill a pepper-box with fine iron-filings,

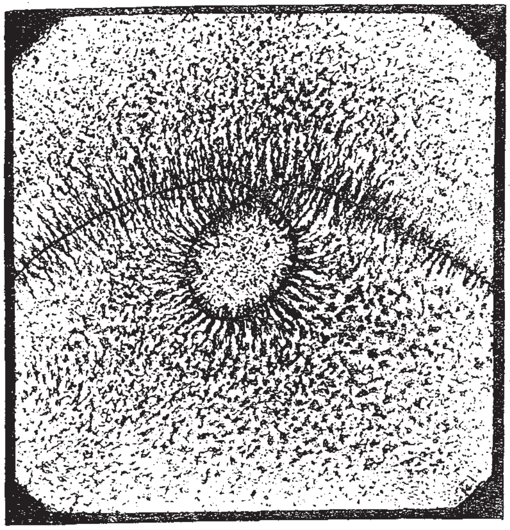

FIG. 5.

and sprinkle them evenly over the sheet; then tap the sheet gently, until the filings have arranged themselves. Observe (Fig. 1) that the lines of force run across from pole to pole. A line of force represents the direction in which the forces act. Suppose that the pole on the right is the north-seeking pole, and that on the left a south-seeking pole. The forces act across the space between them in

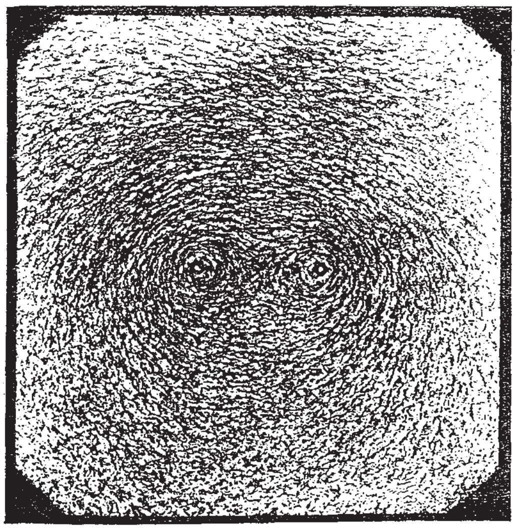

FIG. 6.

the continuous curves from pole to pole. Suppose you could obtain a piece of steel imbued with magnetism of one kind of polarity only—a magnetic "particle," in fact, of the same kind of magnetism as the north-seeking pole. If you were to put that magnetic particle down on one of these lines near the north-seeking pole on the right, it would, as we know, be repelled away, since similar poles repel one another. And it would move away along the line of force (for that line of force represents the direction in which the force acts), and would pass right over and be attracted to the south-seeking pole on the left. Similarly a magnetic particle of south-seeking polarity, if we could get one and place it down on a line of force, would be driven along the line in the opposite direction.

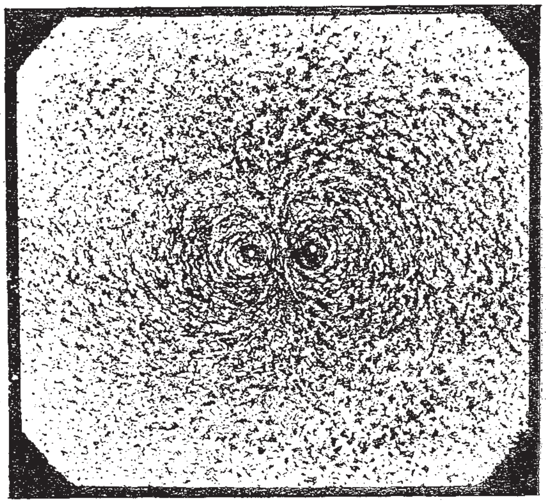

FIG. 7.

Notice, too, that a great many of the lines of force that run out of one pole run into the attracting pole opposite. This you will find always to be the case when two poles attract: their lines of force run into one another.

As a second experiment lay down the two magnets, but put their north-seeking poles towards one another, and then lay on them a sheet of card or glass, and sprinkle

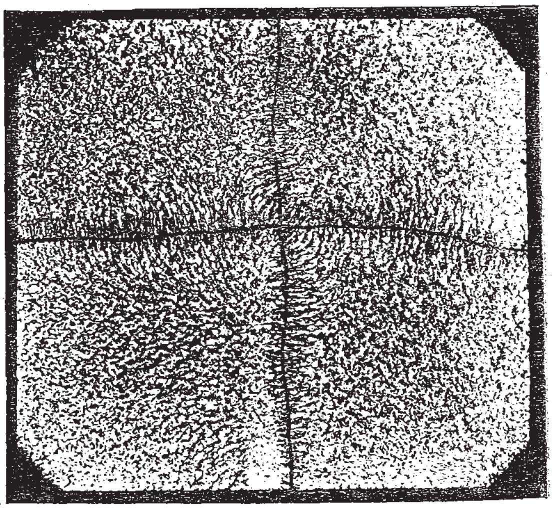

FIG. 8.

filings over, as before. The curves you obtain, which are like those of Fig. 2, are quite different from those obtained before. This time the lines do not run across from pole to pole. They start out, but instead of uniting and blending together, and bending over to run into one another, they turn away sharply where they encounter one another, and, without ever joining, swerve aside in

almost parallel paths. If our supposed particle of north-seeking magnetism were placed on a line near one pole it would not pass over from pole to pole, but would follow the line where it swerves away to the side. We know (by experiment) that two north-seeking poles repel one another, and we see here that the lines of force of two such poles never run into one another, but turn aside mutually repellant. You will find that this is always the case when two poles repel.

Such experiments as these led Faraday to enunciate several simple yet most important principles concerning the lines of force, by means of which we can learn from the lines what kind of action they will produce, whether attraction, or repulsion, or rotation. *Firstly.*—All lines of force tend to shorten themselves. If the lines running across in our first figure were replaced by actual threads of stretched elastic material, we see that any "shortening" of them would bring the poles nearer together, which, indeed, is precisely the tendency of the magnetic attraction between the poles. *Secondly.*—Lines of force repel each other when placed side by side. If this be the case then the lines in our second figure, which bend outwards, and run off side by side, repel one another, the two poles must be experiencing a tendency to move away from one another; and this we know is the case. *Thirdly*, Like magnetic lines of force, when "end on" to each other, run into each other; while, unlike magnetic lines, when end on, repel each other. Here, of course, we apply the terms "like" and "unlike" to the cases of the directions in which our supposed particle of north-seeking magnetism would move along the lines. These notions of Faraday's are full of meaning, and it is not many years since Prof. Clerk Maxwell showed how well they agreed with the most perfect mathematical expression of the forces that operate in the medium filling the surrounding space.

Keeping these simple principles in mind, let us apply them to some further cases of magnetic action, and see if they are equally applicable. We know that the wires carrying electric currents possess certain magnetic properties, and will deflect magnetic needles; that two electric currents may attract or repel each other; and that current may make a magnet pole rotate round it. Can we explain such electrodynamic actions also by applying the principles of Faraday to the magnetic lines of force existing in these various cases?

In the first place, what are the lines of force belonging to a wire through which an electric current is passing? To ascertain this we will bore a hole through a card or a piece of glass, and pass a wire up through the hole. Then, joining the ends of the wire to the poles of a powerful battery, we will, while the current is passing, sprinkle on iron filings, and, tapping lightly, will permit them to assume their places in the lines of force. Fig. 3 was thus obtained. It shows us a series of concentric circles. If a supposed north-seeking magnetic particle were put down on one of these circles it would move round and round in one direction; supposing the current to come up through the hole, this direction would be opposite to that of the hands of a watch. If the current went down through the hole, the movement would be the other way round. But we may examine the current in another way. Lay the conducting-wire down flat, and place over it the card or piece of glass. The forms assumed by the iron filings are in this case (Fig. 4) straight lines across the wire—are edge-views, so to speak, of the systems of circles we just now obtained.

These two figures were discovered by Faraday, and are given in his researches. They are also given by Dr. F. Guthrie in his book on "Magnetism and Electricity."

If we wind up our conducting-wire into a simple knot or loop, carefully preventing the overlapping parts from touching, the figure obtained with the iron filings is like that of Fig. 5. It is interesting to observe how in the middle of the loop there are no lines, only dots. The lines of force run through the loop, perpendicularly to its plane, and we only see them end-ways as points. It is clear that a magnetic particle such as we have imagined would be either attracted into the middle of the loop, or would be repelled out of it, according to its polarity.

Now what is the effect of carrying two parallel currents through two wires side by side? Take a piece of card or glass, as in Fig. 6, having two holes in it; through these pass a couple of wires joined to two batteries, so that the two currents are either both ascending or both descending through the flat surface. The magnetic field mapped out by the iron filings will then show a series of curves, the outermost of which are rough ovals inclosing both the currents, whilst the innermost are small ovals round each wire. The lines between the inner and outer systems present a sort of hour-glass shape or *lemniscate.* Had the two parallel currents, however, passed in opposite directions through the plate, one ascending and the other descending, the filings in the magnetic field would have taken the form given in Fig. 7. Here we find two separate systems of distorted and flattened circles surrounding the wires, each separate system of circles having displaced the other. The outer curves do not run into each other as in the preceding case. Let us apply Faraday's principles to these two figures. In the former (Fig. 6) any "shortening" of the exterior lines would tend to draw the centres nearer together. In the latter case (Fig. 7) no such consequence need result. A tendency of the successive lines to repel each other and to maintain equal distances from each other, would in the former case tend to reduce the entire figure to a system of concentric circles, which could not be accomplished unless the two centres approached each other and coalesced. In the latter case, since the systems of lines round the two centres never join across, this tendency would have the result of driving the two centres far apart to allow of the lines becoming perfect sets of circles. Now we know from Ampère's classical researches on parallel currents, that they attract one another when they run in the same direction, but are mutually repellant when they run in opposite directions. Our application of Faraday's principle enables us to foresee this electro-dynamical action as a consequence of the distribution of magnetic force in the field. In an exactly similar manner we may reason out the action of the forces in the field which is produced by two currents crossing one another at a right-angle (Fig. 8), the conducting wires attracting one another across those quadrants in which the currents flow both towards or both from the point of intersection.

We may apply our study further and investigate, with iron-filings, the action which currents exert on magnets. Let us conduct a current vertically through a hole in a plate, and fix near it a small magnetic needle, as in Fig. 9. The needle has been placed so as to point with one pole towards the current. The lines of force radiating from that pole run round and coalesce on one side with the circular lines of force of the current. On the other side of the pole they absolutely refuse to unite with the circles, and repel them away. Clearly, the "tendency to shorten," which Faraday predicated of the lines, would drag the pole of the magnet in one direction round the current. Looking at the other pole of the magnet we see that the tendency acts in the opposite direction, so that the total result would be a tendency to turn round the magnet about its middle point, and set it at right angles to its present position. This consequence, too, is, as we know from Oersted's famous experiments, the fact.

If, instead of laying the needle down flat, we had reared it up on end, as in our Fig. 10, where a square black

spot marks the place of the pole, we should perceive that the systems of circles round the current and of rays round the pole mutually disturbed each other, and that the figure was consequently unsymmetrical. Round one half of the figure the lines coalesce; round the other they repel each other, and stream away. Applying the notions we have already obtained, we see that the result will be a

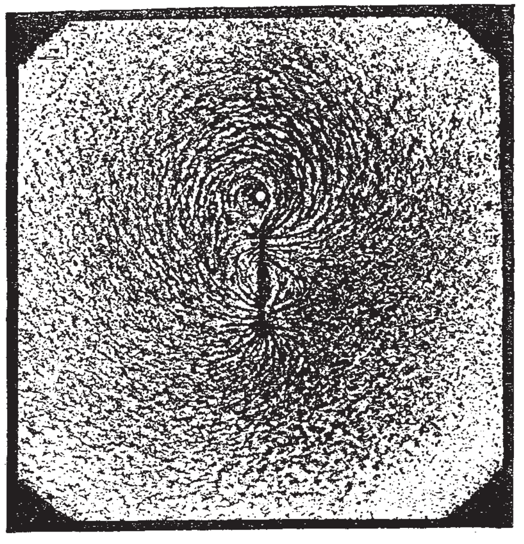

FIG. 9.

force tending to make the pole and the current rotate round each other. This, we know, was shown by Faraday himself to be the case, for when one was fixed and the other free to move, the one rotated round the other. Carry on the idea one stage further, and make the current run up through the plate at the precise point where the pole

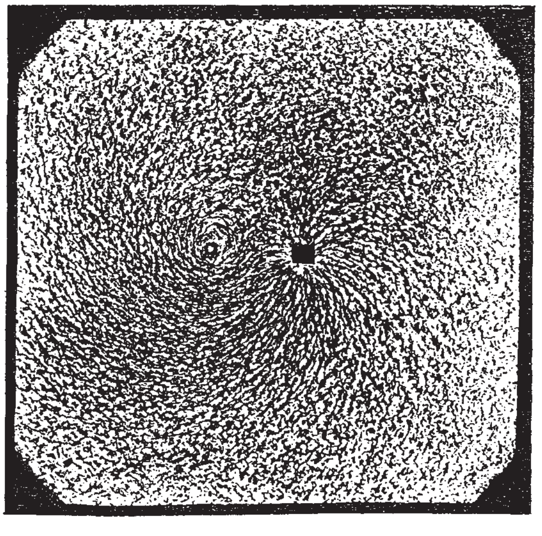

FIG. 10.

of the magnet is. Let it run up through the magnet. The "field" we obtain (Fig. 11) shows us neither the rays of the magnet nor the circles of the current, but a set of beautiful spirals unwinding from a common centre. What kind of motion can we deduce from this remarkable figure? If the branches of the spiral could shorten themselves they would certainly rotate the central region round on itself. The corresponding fact exists in another of Faraday's discoveries: that a magnet can be made to rotate round its own axis, under the influence of a current running up it through one of its poles.

One experiment more will close for the present our

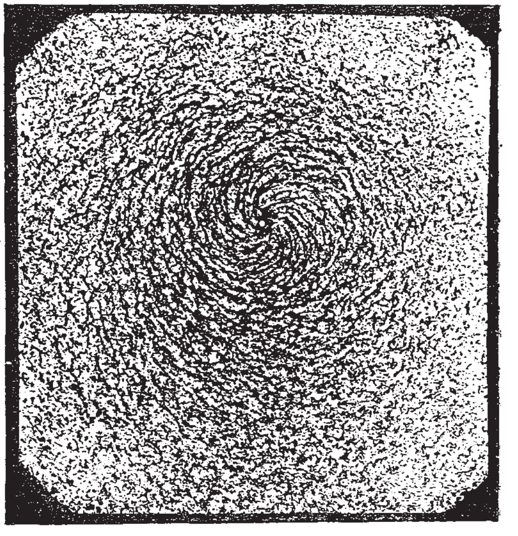

FIG. 11.

study in magnetism. We know that a rod of iron becomes a magnet when we wind a spiral of wire round it and send a current through the wire. There must be some relation between the iron bar and the coils of wire: what is it? Let us investigate this also by looking at the distribution of the lines of force within the coil.

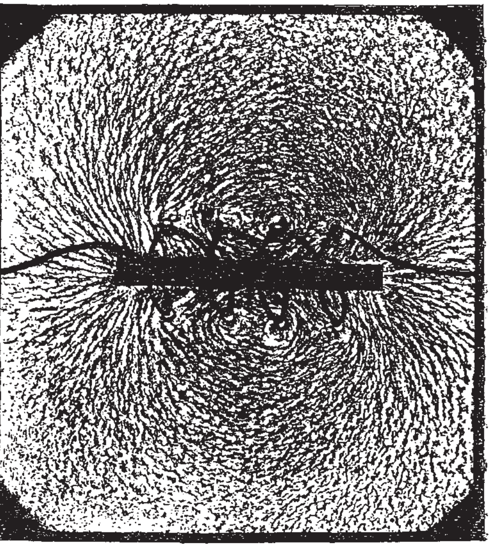

FIG. 12.

Take a plate of glass or a piece of card and bore eight holes through it, as in Fig. 12, and wind a corkscrew of wire in and out; then lay a little bit of thin, soft iron down the middle. We see by the lines of force, when the current is passed, that the iron becomes a strong magnet, but that the wires at the same time are mag-

netic also. We shall discover also that the magnetism of the little iron bar is not distributed exactly in the same way as if it had been a permanent steel magnet, for the lines of force follow curves that fill surrounding space slightly differently. Still, on the whole, we should argue that the iron core possessed magnetic poles where the force was greatest, and that the two poles were of opposite kinds of polarity, one being a north-seeking, the other a south-seeking, pole.

SILVANUS P. THOMPSON

THE LATE MR. G. DAWSON ROWLEY

IT is with sincere regret that we have to announce the death, on the 21st inst., at his house in Brighton, of Mr. George Dawson Rowley, the projector of, and principal contributor to, the *Ornithological Miscellany*, which he published at his own very considerable cost, and author of several papers on ornithological and archæological subjects. Educated at Eton and Trinity College, Cambridge, where he graduated B.A. in 1846, he was the companion, both at school and at the University, of the late John Wolley, whose early passion for natural history he shared. In Mr. Rowley, however, the taste for a time gave way to antiquarian studies, and did not return, at any rate very strongly, until some years afterwards, when he had married and was settled at Brighton, where, notwithstanding the *dictum* of Mr. Ruskin that "no English gentleman has ever thought of birds except as flying targets or flavorous dishes," he became, so far as the opportunities of the place allowed, a very watchful observer of all that was passing in the feathered world, while in the spring he yearly repaired to his father's estate at St. Neot's in Huntingdonshire, the better to study the habits of birds in the breeding-season. He also began to form a collection of ornithological specimens of singular value, sparing no cost or trouble in the acquisition of objects of rarity or peculiar interest, and the treasures thus amassed finally became very numerous. The design of his *Ornithological Miscellany* seems to have chiefly been to illustrate this "Rarity Chamber"—for so, after the example set by old Rumphius, it might well be called—a considerable number if not most of the specimens therein figured or described being his own possessions. Yet he willingly accorded room in its pages to worthy contributors, among whom may be mentioned Mr. Dresser, Dr. Finsch, Messrs. Salvin, Sclater, Seebohm and Sharpe, and Lord Tweeddale, and his printing a translation of Prjevalsky's important work on the birds of Turkestan, published in Russian, with copies of the plates, was a real boon to those ignorant of that language. Besides this he often wandered into the by-ways of ornithology, which frequently possess a curious kind of interest, and he gave views of many places remarkable for the birds which frequent them. Never did the contents of a work better justify its title, for anything more miscellaneous than they are cannot well be imagined. Failing health, as he himself only a few months ago stated in his concluding remarks, brought it to an end far sooner than he had intended. Setting aside the scientific value of some of the papers, the beautiful plates by which nearly all are illustrated make its cessation a loss to ornithologists; and those who knew that Mr. Rowley had for a long time been gathering information bearing on the history of the extinct Gare-fowl (*Alca impennis*) had hoped that some result of his labours in this respect would one day make its appearance. But this was not to be. More than a year ago a violent hæmorrhage of the lungs gave warning of serious danger, and the attack was only too quickly followed by others of a like nature, under which he sank, in his fifty-seventh year, dying, by a singular coincidence, on the very same day as his father, who had long been an invalid.

NOTES

WE notice with regret the death, at the age of sixty-eight, of Mr. James M'Nab, the well-known curator of the Edinburgh Royal Botanic Garden. Mr. M'Nab's father was also curator of the Edinburgh Botanic Garden, where the son was trained. In 1834 Mr. M'Nab paid a visit to the United States and Canada, the fruits of which appeared in a variety of contributions, descriptive of the more interesting plants found during the journey, in the *Edinburgh Philosophical Journal* for 1835, and in the *Transactions* of that period of the Edinburgh Botanical Society. On the death of his father, in December, 1848, after thirty-eight years' superintendence of the Botanic Garden, Mr. M'Nab was promoted by the Regius Professor (Dr. Balfour) to the responsible post thus vacated. The extent of the Garden at that time was not more than fourteen imperial acres. Ten years later, however, two acres were added on the west side, which were laid out and planted by Mr. M'Nab, under the superintendence of Prof. Balfour. After the lapse of five more years the Experimental Garden, extending to ten acres, was thrown into the Botanic Garden, and planted with conifers and other kinds of evergreens. On a portion of the ground so acquired a Rock Garden was, on the suggestion of Mr. M'Nab, begun towards the end of 1860. The Rockery has now upwards of 5,442 "compartments" for the cultivation of Alpine and dwarf herbaceous plants, and is yearly being added to; while of late years portions of the southern slopes have been set apart for the rearing of bulbous and other plants, whose roots require to be well ripened before flowering. Mr. M'Nab was a frequent contributor to horticultural and other magazines, his writings including papers, not only on botanical subjects, but on vegetable climatology, landscape gardening, and arboriculture. One of the original members of the Edinburgh Botanical Society, founded in 1836, he was a voluminous writer in its *Transactions*; and in 1872 he was elected to the presidency of the society—a position rarely held by a practical gardener. In November of the following year Mr. M'Nab delivered his presidential address on "The Effects of Climate during the last Half-Century with Reference to the Cultivation of Plants in the Royal Botanic Garden of Edinburgh and elsewhere in Scotland," a paper which excited a good deal of discussion at the time, the writer having adduced facts with the view of showing that a change in our climate had taken place during the period in question. Mr. M'Nab also contributed to the Society a monthly report on thermometrical readings and progress of open-air vegetation in the Botanic Garden, which was highly valued, alike by horticulturists and meteorologists, for the practical information it conveyed. Prof. M'Nab, of the Royal College of Science, Dublin, is a son of the late Mr. M'Nab.

ON Friday a meeting of the local executive of the British Association was held at Sheffield to appoint committees to make the necessary preparations for the visit which commences on August 20 next year. The Master Cutler (Mr. W. H. Brittain) presided. It was stated that the guarantee fund now amounted to 3,338*l.*, and would eventually reach 5,000*l.* The Association, however, do not wish the expenses to exceed 1,500*l.*, or they fear that the expense of entertaining the Association will deter other towns from sending invitations. It is expected that at least 1,500 members and associates will attend the sittings. The necessary committees were appointed, and Mr. J. E. H. Gordon, who was present representing the Association, thanked the people of Sheffield for the splendid preparations they were making for the reception of the Association and for the hospitality which was already offered.

M. BARDOUX has appointed a great commission for the reorganisation of the Museum of Natural History of Paris. This